E.7. Phénomènes précurseurs du claquage dans le polyéthylène

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Résumé:

Des échantillons de Polyéthylène Basse Densité (PEBD) munis d'électrodes semiconductrices ont été soumis pendant plusieurs heures à des gradients importants croissant progressivement de 50 à 130 kV/mm à la température de 50° C et 60 °C.

En utilisant la méthode de l'Onde Thermique, nous avons observé en fonction de la contrainte électrique l'évolution de la répartition des charges d'espace restante. Les résultats montrent le développement de la charge injectée dans l'échantillon. Ces effets sont à associer avec les instabilités de courant dans les caractéristiques I(t) et avec le diagramme.

Les études ont été ainsi menées jusqu'au claquage : un modèle a alors été développé tenant compte de l'injection et de la cinétique du développement de la charge d'espace : il rend compte des observations et du claquage .

E.7. Precursor phenomena on the breakdown of polyethylene

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Abstract:

Low density polyethylene (LDPE) samples provided with semi-conductive electrodes have been submitted during several hours to high electric field gradually increasing from 50 KV/mm to 130 KV/mm at 50 °C and 60 °C.

Using the thermal step method, the evolution of space charge distribution is observed with electrical stress variations. Results show the development of injected charges in the sample. The injection is also perceptible by conductivity measurements whith current instabilities and with Schottky diagram.

The studies are led to the electric breakdown of the sample. A model has been developed by considering the injection and the cinetic of space charge development leading to the breakdown.

Introduction

The appearance of space charges in polymers submitted to high electric field is a phenomenon which preoccupies cables makers and cables users because space charges induce a local electric field which can accelerate the ageing of the cable insulation. In this paper, we follow step by step, with the thermal step method and conductivity measurements, the installation of space charges in polyethylene sample submitted to increasing electric field. We show that space charges induce a very high remaining electric field, superposed to the external applied field, leading to an electric breakdown initiated close to the anode.

Experimental procedure

Sample description

Samples are low density polyethylene plaques (thickness:1 mm, diameter:150 mm) provided with semiconductive electrodes (resin doped with carbon black) pressed on each side. The electrode diameter is 20 mm and thickness is 0.5 mm.

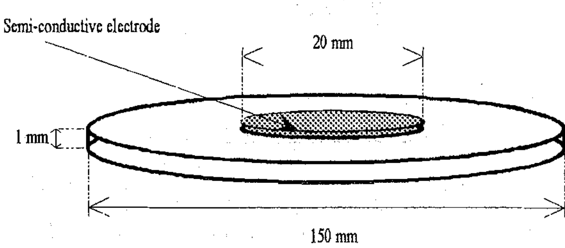

figure 1 : polyethylene sample

Description of the Thermal Step Method

The thermal step method developed by A. Toureille, is based on measurements of the thermodilatation current caused by the application of a so called thermal step. The sample is at room temperature. The temperature of one side of the sample is then quickly cooled to -20°C while the other side is kept at room temperature. The propagation of negative thermal step through the sample leads to thermal contraction of the successive material layers and will thus displace the space charges in the layers. The displacements will modify the equilibrium of the image charges on the electrodes and thus create a current in the external circuit joining the two electrodes.

The current is:

$$I(t) = -\alpha . C . \int_0^D E(x) . \frac{\delta T}{\delta t} . dx$$

where $\alpha = \alpha_x - \alpha_\varepsilon$ with

α_x linear expansion coefficient of material
α_ε thermal dependence of permittivity coefficient
C: Capacitance of sample
T: Temperature
D: Thickness of sample
E(x): Electric field strength in elementary thickness dx

$$\alpha = \frac{1}{l} . \frac{\delta l}{\delta T} - \frac{1}{\varepsilon} . \frac{\delta \varepsilon}{dT} = -\frac{1}{C} . \frac{\delta C}{\delta T}$$

α is obtained by the measurement of capacitance under different temperatures .
The space charge and electric field distributions are calculated from the current by a deconvolution algorithm developed at the Laboratoire d' Electrotechnique de Montpellier. The theory and the numeric treatment (Fourier series or derivation) have been described in detail in previous papers [1,2,3].

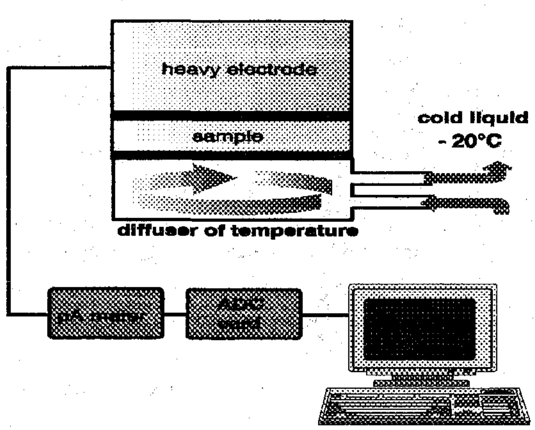

figure 2 : Experimental cell